(12) UK Patent Application (19) GB (11) 2 158 757 A

(43) Application published 20 Nov 1985

(21) Application No 8511840

(22) Date of filing 10 May 1985

(30) Priority data

(31) 1855 (32) 14 May 1984 (33) HU

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(51) INT CL[4]
B23K 20/16

(52) Domestic classification
B3R 14 17X 61 6
U1S 1469 1573 1820 1957 1969 1976 1987 B3R

(56) Documents cited
GB A 2095604 GB 1222905

(58) Field of search
B3R

# (54) Hot press welding process

(57) In hot-press welding of components (1), in particular made of thin materials, a coherent bond (3) between the components (1) is achieved by deforming a deformable auxiliary material (2) placed against each of the components (1) to be joined. The deformation causes disruption of an oxide layer on the surfaces of the components (1) so that a metal to metal bond can be formed between each of the components and the auxiliary material.

The process can be preferably used for producing a metalic bond consisting of the same material throughout the bond between the structural parts of a heat-exchanger.

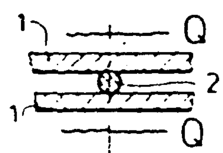


Fig.1

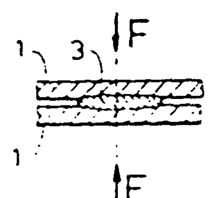


Fig.2

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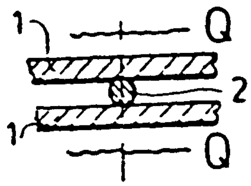


Fig.1

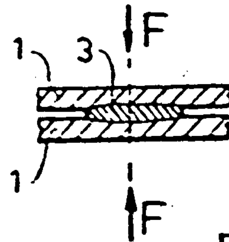


Fig.2

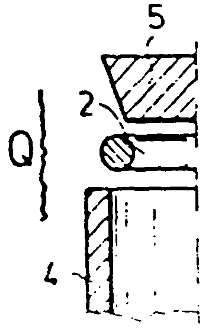


Fig.3

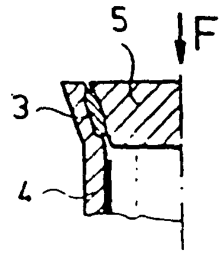


Fig.4

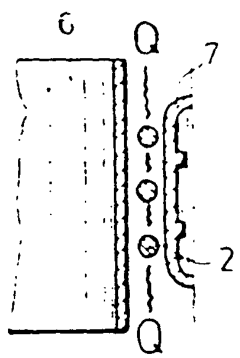


Fig.5

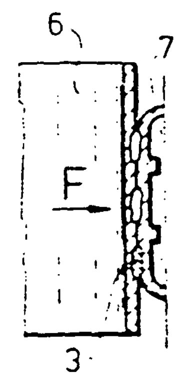


Fig.6

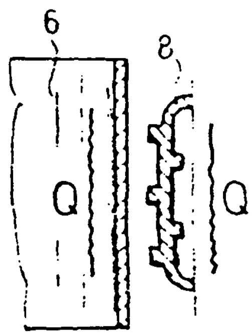


Fig.7

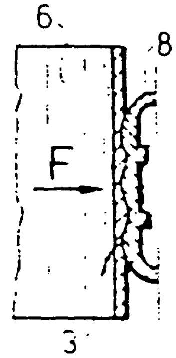


Fig.8

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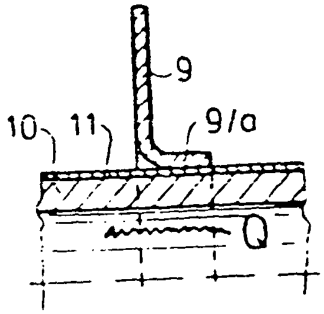


Fig.9

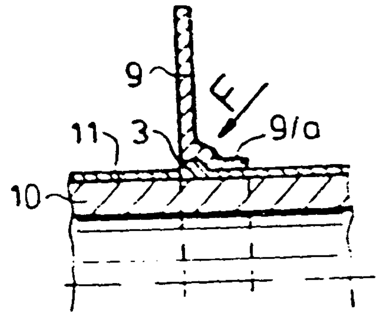


Fig.10

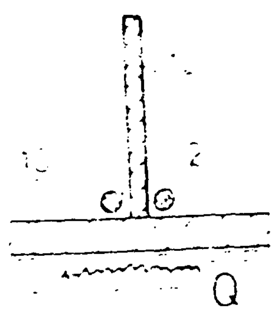


Fig.11

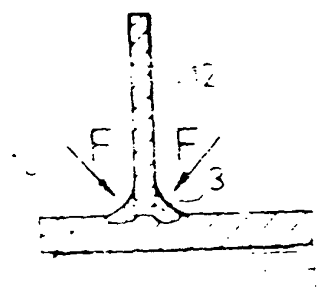


Fig.12

SPECIFICATION

## Hot press welding process

The invention relates to hot-press welding of components in particular those made of thin material, ither to join two componts together or to join several components to one further component. In the course of the process, a coherent bond between the components is achieved be deforming a deformable auxilary material causing rupture of mechanical material formed on the surfaces of the two or more components.

The process can be expediently used for producing a metallic bond between the components of heat-exchangers of different types, geometry and material, while the bond is formed from the same material as the components.

Processes are known in which the assembled parts, whose surfaces have been previously prepared, are dipped into a molten metal bath in order to provide a uniform metal coat on the surface, and at the same time, the coating metal provides a metallic bond between the structural parts. These metal baths consist of heavy metals of low melting point and of their alloys. These are expensive and their use is energy-consuming (i.e. Sn, Sn + Pb, Zn baths).

In other processes, the components to be assembled are coated in advance -partly or entirely -with said heavy metals or their alloys; thereafter the assembled jointless components are covered with a fluxing agent and by heating in a furnace or with a gas-flame they are heated to the melting temperature of the coating metal, as a consequence the metal coating on the surface is melted. Due to inaccuracies of assembly this solution is not at all reliable; in addition, the requirement of heavy metals is too high. Such solutions are described in Hungarian Patents HU-PS 154,673, HU-PS 157,652 and HU-PS 157,652 (Figures 11, 12 and 15).

Processes are also known in which the parts are bonded by electric arc welding, shielded arc welding, electric spot welding, ultrasonic welding, e.g. flame-or plasma welding. These processes require a lot of equipment, the productivity is low and, due to known difficulties of welding and soldering, they are unsuitable for use with light metals. Such a solution is to be found in the patent GB-PS 1,245,580.

In another process, these difficulties are eliminated; the components are glued together with synethetic materials. However, the bonds produced are not sufficiently stable and the required surface preparation is very complicated. The structure of the gluing material is different from that of the metal and in particular, it cannot conduct either heat or electricity. The bonds are unsuitable for parts that are subject, over an extended period of time, to an elevated temperature since the adhesive decomposes and the stress resulting from differential thermal expansion breaks the adhesive down. This solution is partly described in Hungarian Patent Application No.2415 80.

Processes are also known in which structural parts are fixed to other components by electric spot welding or ultrasonic welding simultaneously with production. Although - compared to the previously described similar solutions - these represent an advantag in terms f productivity, the technological disadvantag cannot be eliminated. Such a solution is specified in the Hungarian Patent HU-PS 175,919.

Heat-exchangers are known in which a mechanical connection is formed between structural elements carrying the cooling medium and the heat radiating ribs. As there is no coherent contact, a heat-barrier is formed between the contacting surfaces, accordingly, their heat transmission does not comply with requirements. As a consequence of the different expansions of the structural elements and shocks arising during operation, the contacts may separate and their thermal conductivity then deteriorates further. Such a solution is described in Patent Application No.AO-308.

It has also been proposed that structural parts should be joined by hot-press welding the parts directly to one another simultaneously with their production. However, said solutions are not successfully applicable to structures made of thin material as the percentage of material formation needed for hot-press welding (30%) requires a very high presure force or a very high operational temperature in the case of thin materials. These two technological conditions disadvantageously influence material structure, strength, and density of the unit to be produced.

All the processes proposed place considerable demands on manufacturing equipment in respect of strength and heat resistance and as a consequence, the dimensions of the components being assembled must be large to accommodate such equipment and consequently it is not possible to form densely packed components or high ribs in heat-exchangers, although both geometric requirements form the basis of modern construction and production of heat-exchangers.

In general it can be stated that known bonding processes used in manufacturing equipment have always required thicker materials to be used than needed for the operation of the equipment itself. As a consequence, equipment has been produced with far more material, at higher costs and with an excess-weight, than required.

High strength and thermal load requirements involved with known processes have not enabled production of compact heat-exchangers; bonds could only be formed with the same material as components and only heat-exchangers with symmetrically arranged elements with equal countersupport could be produced.

Such solutions are propsed e.g. in the British Patent GB- PS 1,273,141 and in the Hungarian patent HU-PS 175,919.

Compared to prior art, the present invention represents a progressive process based on new recognitions, eliminating deficiences of known solutions and yielding increased reliability, as:

- it guarantees higher productivity,
- the bond formed by the process according to the invention is more stable (higher strength can

be achieved) and useful life is also longer,

– from the point of view of heat flux a more advantageous coherent bond can be obtained,

– the bond thus formed resists well extreme loads, heat and vibration.

The invention is based on the following recognitions: Two thin sheets (0.1 to 0.3 mm) can be welded by hotpressing welding in such a manner that onto the defined place of connection an auxiliary material is placed, the thickness of which surpasses by an order of magnitude the thickness of the sheet - e.g. Ø - and after having heated the components to the temperature of hot-press welding; the two sheets facing each other are pressed with the force F, as a consequence, the auxiliary material will be deformed perpendicularly to the direction of the force F, while the two sheets are welded on the deformed surface.

With light metals, the performance of hot-press welding is prevented by the elastic oxide layer continuously and repeatedly fromed on the surface. In a material with a thin cross-section it is most difficult to produce a deformation which can rupture the oxide layer. The novelty of our invention lies in that the deformable auxiliary material adheres to the surface part to be welded and due to its advanced deformation it carries the surface oxide layer with it; as a consequence, contact is obtained on a clean metal surface and thus a metallurgic bond is obtained.

One of the prequisites of performing hot-press welding lies in the large amount of material that is moved during welding, the magnitude of which amounts to about 30 to 50% of the cross- section. The invention is based on the recognition that the deformable auxiliary material inserted between the surfaces to be welded is pressed into the surface of the materials to be welded under the influence of a force F, auxiliary material is further deformed by the force F, and the auxiliary material is flattened and the sliding material carries away the crystallites on the surfaces to be welded with it. The particles of the deformed material key into the micro-surface formed in the crystal lattice resulting from the displacement of the surface material, and as a consequence, a coherent bond is established.

Formation of heat-press weldings depends on temperature, time and compressive strengh. If time and temperature are fixed, formation of the bond will be influenced by the specific compressive force. The invention lies in that a unit compressive force gives rise to a deforming, highly effective compressive pressure due to the fact that the force is concentrated only on the cross-section of the auxiliary material to be deformed, and this force represents only a fraction of the force compared to that needed if the sheet-surfaces to be welded had to be pressed.

The invention is also based on the recognition that if the deformable auxiliary material is used as a resistance heating element by passing electricity through it, in addition to the heating of the auxiliary material, radiated heat pre-heats also the neighbouring surfaces to be welded. When performing hot-press welding, the hottest deformable auxiliary mat rial results in a considerable deformation even if the compressive force F is small since the particles in the crystal lattice of the surfaces to be welded become more activated.

A further characteristic of the invention lies in that when used with light metals, the electrical resistance of light metals increases with rising temperature, as a consequence, at a given electric output, the deformable auxiliary material heats itself when an electric current is passed through it.

We have also recognised that in the course of prefabrication, the deforming auxiliary material may be part of at least one of the surface parts to be welded. This auxiliary material, which is of reduced cross-section, becomes deformed in the course of hot-press welding and a coherent connection is established with the counterpart component.

With pressure-proof vessels, stable solid and homogeneous bonds can be formed by using the process according to the invention resulting in a considerable technological advantage in the case of vessels made of light metals.

It is characteristic for the invention that by using the process proposed, components with different material thicknesses can be interconnected, so e.g. in the course of the production of heat-exchangers, ribs or lamellae made of thin sheet material can be welded to media-conducting pipes with thicker walls that tolerate pressure and corrosion.

A further advantageous characteristic of the invention lies in that pipes having thinner walls can also be used for conducting the media since by using the process according to the invention, the deforming auxiliary material is welded into the thin wall of the pipe in course of hot-press welding, thus reinforcing and not weakening it.

According to measurements, heat-resistances are as follows:

- with mechanical bonds, with Al/Al structural materials heat resistance amounts to 0.05 kW/m°C;

- with soldered Cu/Cu structural material heat resistance amounts to 0.025 KW/m°C;

- using aluminium deformable auxiliary material heat resistance of the coherent bond amounts to 0.01 kW/m².

Furthermore, we recognised that the heat transfer ability of bonds formed by hot-press welding and using deformable auxiliary materials arranged at predetermined distances surpasses the heat transfer capacity of known joining methods. In such a manner heat exchangers with a high efficiency can be produced.

A further recognition lies in that when using the hot-press welding process and the deformable auxiliary material neither fluxing agent nor covering material is needed. The bonds formed using the same metal throughout the bond by hot-press welding yield equipment with a long useful life that resists corrosion without any aftertreatment.

We found that bonds formed using deformable auxiliary material identical to the material of the bonded components have the same strength as the basic material of the components, they are resist-

ant to vibration, repeated thermal loads and they are insensitive to fatigue.

The invention will be described in detail by means of the accompanying drawings. Taking into consideration that the process according to the invention is mainly applicable in heat-exchanger production, the examples are taken from this field of application.

*Figure 1* is a sectional view of a pair of sheets prepared for hot-press welding.

*Figure 2* shows in section view the pair of sheets according to Figure 1 once they have been welded.

*Figure 3* is a sectional view of part of the end of a pipe with a plug prepared for hot-press welding to it;

*Figure 4* is a sectional view of the pipe end and plug according to Figure 3 joined by welding;

*Figure 5* shows in sectional view, a part of a heat-exchanger with the flat fin having inner ribs for conducting the heat- exchanger medium, and a heatable deformable auxiliary material prepared for hot-press welding;

*Figure 6* is a sectional view of the welded parts according to Figure 5;

*Figure 7* shows a sectional view of a part of a heat-exchanger provided with deforming ribs on a flat surface of a fin for conducting a heat-exchanger medium;

*Figure 8* is the section view of the part of Figure 7.

*Figure 9* is a sectional view of part of a heat-exchanger with an oval or cylindrical pipe, a flanged lamella prepared for hot-press welding using the deformable auxiliary material;

*Figure 10* shows a sectional view of the parts of Figures 9 in a welded state:

*Figure 11* illustrates a cylindrical or oval pipe with ribs formed helically or as rings and a deformable auxiliary material prepared for hot-press welding, and

*Figure 12* shows a sectional view of the parts according to Figure 11 in a joined state.

The surfaces of the sheets shown in Figures 1 are clean to metal, between them auxiliary material 2 is arranged, the diameter of which is larger than thickness of the sheets and is made of the same material as that of the sheets to be welded. A radiator for pre-heating for the hot-press welding process is indicated with the reference letter Q.

Figure 2 shows the pre-heated sheet 1 joined by hot-press welding under the influence of the force F. A coherent bond 3 was formed by the deformable auxiliary material according to Figure 2 in such a manner that while being flattened, it was built in metallurgically into the material surface lying next to the surfaces of the sheets 1.

Embodiments shown in Figures 1 and 2 can be advantageously used for joining sheets, interconnecting pipewalls and water-chambers of water- and oil-coolers in cars, for connecting electrical wires, as intermediate parts for welding light metals that are hard to weld.

Figure 3 illustrates a deformable auxiliary material 2 matching the opening of a pipe 4 or fin the conical plug fitting the shape of the opening 5 to be closed, as well as a radiator Q for pre-heating the parts to be welded.

The lower part of the closing plug is smaller and the upper part larger than the cross-section of the opening 5 to be closed.

Figure 4 shows the hot-press welding joint formed under the influence of the force F; as is obvious from the Figure, the conical closing plug deforms the end of the pipe 4 or fin. Between the two conical surfaces a coherent bond was established from the deformed auxiliary material 2, which is built-in into the structure of the surfaces that have been welded. Embodiments according to Figures 3 and 4 can be applied for closing the ends of pipes and fins, interconnecting pipes, forming of pipe-reductions, in particular for elements made of aluminium or alloys thereof.

Figure 5 shows a flat-sided body 6 for conducting heat exchanger medium, a profile fin 7, which is folded or bent and which can be provided with inner ribs too, deformable auxiliary material 2, and a radiator Q. If the deformable auxiliary material is connected to an electric supply source, it can be used as an electric resistance heater which can be heated to the temperature of hot-forming. As soon as the heat radiated by the deformable auxiliary material 2 has heated up the surfaces of the fin 7 and body 6 to the temperature of the hot-press welding process, the electric supply source is disconnected and the process of welding can be performed.

It may be expedient if the structural unit to be welded is placed in an insulated vessel during heating to obtain a higher efficiency. The assembled unit can be heated in a heat transfer furnace too, thus reaching the temperature needed for welding.

Figure 6 illustrates a hot-press weld formed under the influences of the force F, the coherent bond 3, which is built- in into the contacting surfaces of the profile fin 7.

Figure 7 shows a flow-conducting body 6, a profile fin 8 which is folded or bent and is provided with outer deformable ribs on its flat side and with inner ribs for improving heat transfer and simultaneously serving as spacers; Q indicates a heater for pre-heating the parts to the welding temperature.

According to the proposed process, a heating insert -serving also as a support - can be arranged inside the profile fin 8, which may transfer heat to the base of the outer ribs. Hotpress welding can be performed in such a manner that the insert presses the outer ribs against the body 6 with such a force that the outer ribs of the profile fin 8 are deformed in the course of the hot-press welding.

In Figure 8 the hot-press welding formed under the influence of the force F is to be seen, where the coherent bond 3 formed from the deformable auxiliary material 2 is built into the material structure of the base of the body 6 contacting the profile fin 8. In the embodiments shown in Figures 5 to 8 fins 7 and 8 can be juxtaposed or superposed in one or more rows, as is already well-known in heat-exchangers. Profile fins 7 and 8 can form a

single or divided flow section for heat-exchange medium and may be attached to the whole or parts only f th bodies 6.

If the inner ribs of profile fins 7 and 8 are formed as cross connections between the parallel sides of the fins 7 and 8, the fins can be used - even if they have thin walls - for conducting media at high pressure. This embodiment can be used for heat exchangers of the liquid/air or gas/air type, e.g. in coolers of cars, air-conditioners, re-coolers, condensers etc.

Figure 9 illustrates a cylindrical or oval pipe 10 with a deformable auxiliary material layer 11 formed thereon by a hot-dipping process or applied onto it in a cold forming process, a lamella 9, part of the lamella flange 9a and a pre-heating radiator Q.

The hot-press welded bond is formed so that, after having heated the auxiliary material layer 11 on the pipe by the heater Q to the temperature of hot-press welding process, the lamellae 9 with the lamella flange 9a are pushed onto the auxiliary material layer 11, meanwhile the lamella flange 9a is also heated from the radiated heat; in the last short phase of the pushing operation the flange 9a is pressed onto the deformable auxiliary material layer 11 with a force giving rise to deformation; in the course of deformation of the inner surface of the flange 9a the oxide layer is removed and the deformed auxiliary material is built-in coherently into the material thereof.

Figure 10 shows the hot-press welding having been formed under the influence of the force F; coherent bond 3 was formed from the deforming auxiliary material layer 11; cylindrical or oval pipe 10, lamellae 9 and lamella flange 9a are also illustrated.

The embodiment seen in Figures 9 and 10 can be preferably used in multi-pipe constructions in dimensions applicable in technical practice in the following fields of application:

industrial and other air-conditioning equipment, such as air-coolers, air-heaters, condensers etc.,

Figure 11 shows a cylindrical or oval pipe 10, a helically formed rib 12, deformable auxiliary material 2, as well as a pre-heating radiator Q.

The pipe is heated to the temperature of hot-press welding by the radiator Q. Expediently, an electric current is passed through the deformable auxiliary material 2 to heat it as described in connection with Figure 5. The helical rib 12 may be wound onto pipe 10, and may be positioned on the pipe 10 using a mandrel, during the course of which the pipe 10 is rotated to wind on to it the deformable auxiliary material, which is in the form of a wire, simultaneously the auxiliary material 2 is deformed continuously at the foot of the rib 12.

Figure 12 illustrates the hot-press weld formed under the influence of the force F; coherent bond 3 was formed from the deformable auxiliary material 2 and it is built in coherently into the structure of the contacting surfaces of the pipe 10 and the rib 12.

The coherently bonded and ribbed pipes according to Figures 11 and 12 can be produced in a length and dimensional range accepted in technical practice. They can be used as convective heat-exchangers in equipment subjected to considerabl temperature fluctuations made mainly f steel, in flue pipes of boilers, for regenerating the heat contained in gas in gas-turbines etc.,

As is apparent from Figures 1 to 12, the proposed process can be used within a wide range of application and in a wide range of sizes; compared to known solutions the process according to the invention enables the use of aluminium and alloys thereof and steel and advanced steel alloys.

The process can be adapted with regard to the geometries of the components and is applicable to different fields of application.

## CLAIMS

1. A process for producing one or more hot-press welded bonds between structural elements, the welding being performed continuously or discontinuously, characterised in that at least the contacting surfaces of the structural elements are heated to the temperature of hot-press welding, deformable auxiliary material is placed against the surfaces of each of the elements to be joined, a coherent bond is formed by deforming the auxiliary material plasticly to an extent surpassing 30% under the influence of a force that presses the auxiliary material and each of the components together so that the displaced auxiliary material breaks the crystal lattice of the structural elements and the auxiliary material is coherently built into the crystal structure of said structural elements.

2. A process as claimed in claim 1, charcterised in that an electric current is passed through the deformable auxiliary material so that the material itself acts as an electric resistance heater.

3. A process as claimed in claim 1, characterised in that the auxiliary material is integrally formed with one of the structural elements.

4. A process as claimed in claim 1, characterised in that the deformable auxiliary material layer is formed as a coating on one of the structural elements.

5. A process as claimed in any of the claims 1 to 3, characterised in that the structural elements are made of aluminium or an alloy thereof.

6. A process as claimed in claims 1 or 2, characterised in that the structural elements are made of steel or alloys thereof.

7. A process as claimed in any of the claims 1 to 4, characterised in that the structural elements to be joined are made of different materials.

8. A process as claimed in any of the claims 1 to 7, characterised in that the structural elements are structural elements of heat-exchangers.

9. A process as claimed in any one of claims 1 to 8, characterised in that the deformable auxiliary material is made of the same material as the structural elements.

10. A process as claimed in any one of claims 1 to 9, substantially as hereinbefore described with reference to Figures 1 and 2, Figures 3 and 4, Figures 5 and 6, Figures 7 and 8, Figures 9 and 10 or

Figures 11 and 12.

11. A structure containing joints obtained by the process of any one of claims 1 to 10.

12. A heat-exchanger containing joints obtained by the process of any one of claims 1 to 10.

Printed in the UK for HMSO, D8818935, 9/85, 7102.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.